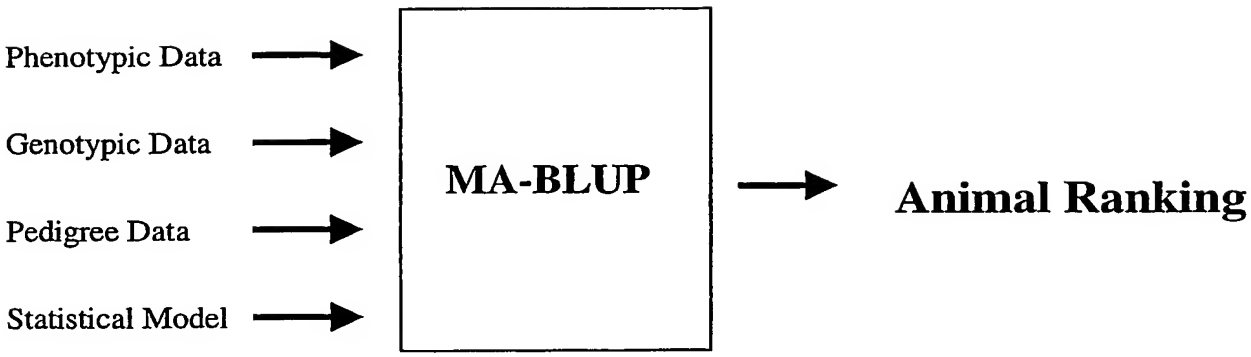

Phenotypic Data
Genotypic Data
Pedigree Data
Statistical Model
MA-BLUP
Animal Ranking

FIGURE 1

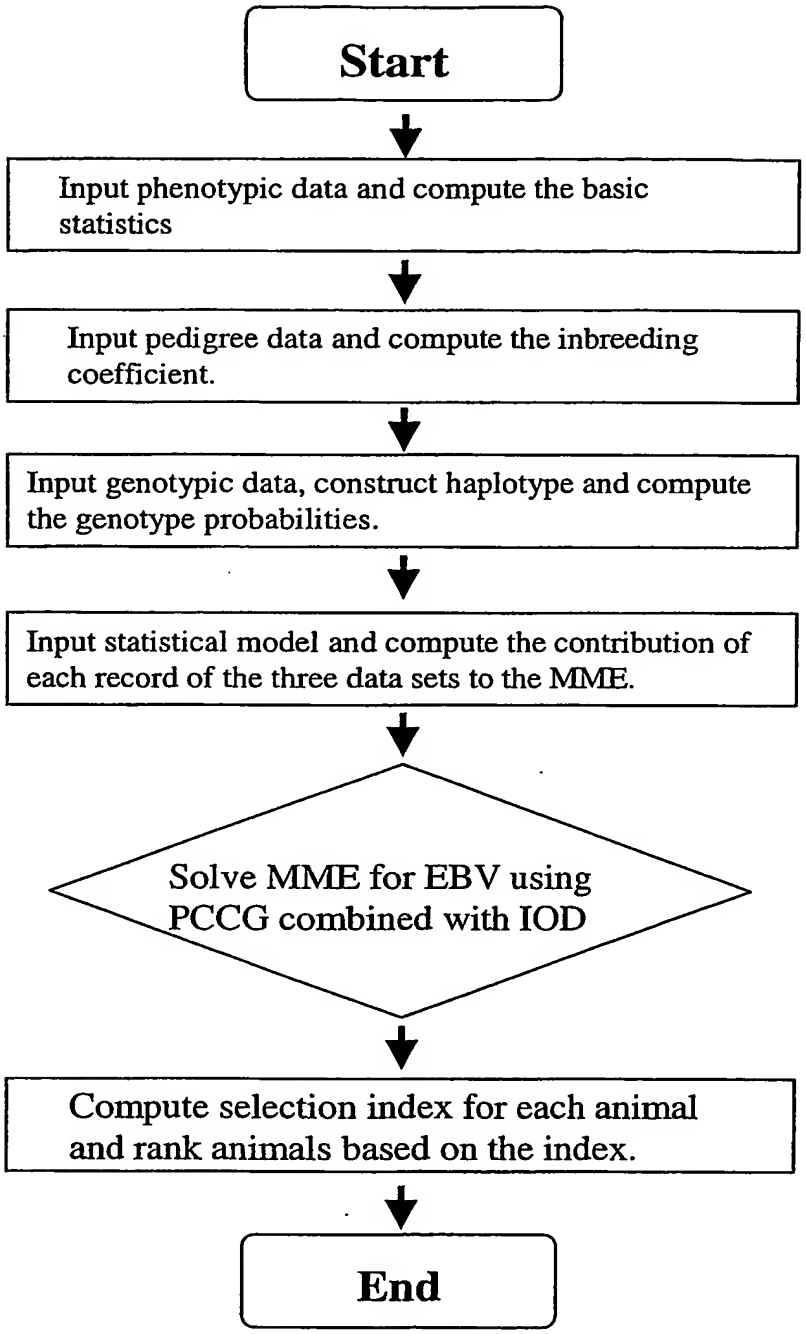

Start
Input phenotypic data and compute the basic statistics
Input pedigree data and compute the inbreeding coefficient.
Input genotypic data, construct haplotype and compute the genotype probabilities.
Input statistical model and compute the contribution of each record of the three data sets to the MME.
Solve MME for EBV using PCCG combined with IOD
Compute selection index for each animal and rank animals based on the index.
End

Figure 2

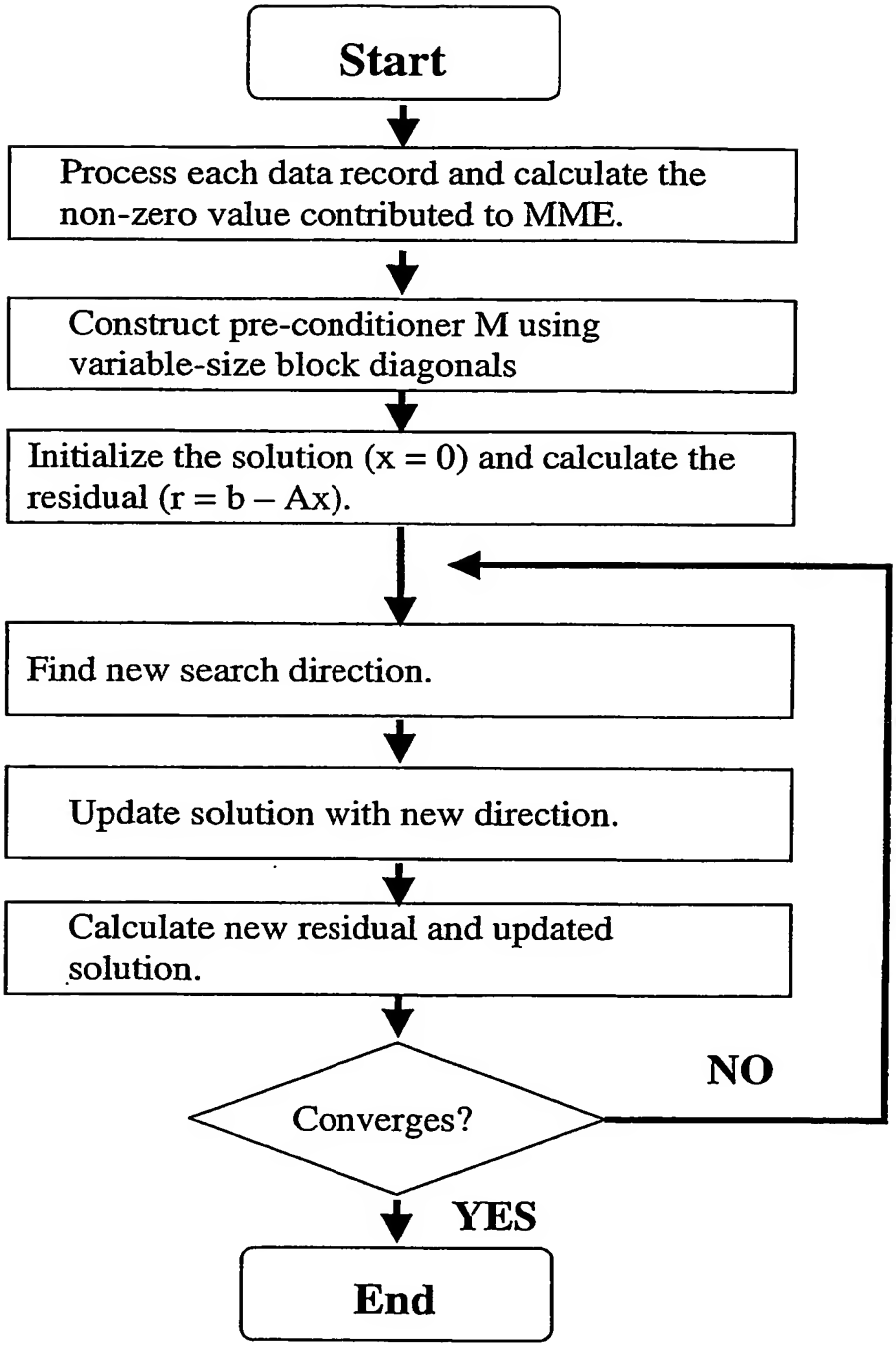

Start
Process each data record and calculate the non-zero value contributed to MME.
Construct pre-conditioner M using variable-size block diagonals
Initialize the solution (x = 0) and calculate the residual (r = b – Ax).
Find new search direction.
Update solution with new direction.
Calculate new residual and updated solution.
Converges?
NO
YES
End

Figure 3

FIGURE 4

```
   1 atgagcttcc tagagcaagg agagagccgt tcatggccat cccgagctgt aaccaccagc
  61 tcagaaagaa gccatgggga ccaggggaac aaggcctcta gatggacaag gcaggaggat
 121 gtagaggaag gggggcctcc gggcccgagg gaaggtgagt tcaaggccag ttctggggag
 181 ctgggactgg gggcagtggg cagtcctcaa acctggggcc cgtctctggt ctggtccctc
 241 cataacacag gcacataaca tcatgcagcc agtctcccca caaggggggag gacaactgca
 301 ttgctgatcc aggggtccag ggatccaagg tggccaactc aggacagagc cactgtcttc
 361 tctgtgactc tctgagactc agctctctca cctgcaaaat ggggccacag cattcaggct
 421 tcccaaggtt gcaatgagga tgaatggaga cagcagatga ggaagttctc tggaagaggg
 481 agttactgtg ctctccctcc cgctccccga acaggtcccc agtccaggcc agttgctgag
 541 tccaccgggc aggaggccac attccccaag gccacaccct tggcccaagc cgctcccttg
 601 gccgaggtgg acaacccccc aacagagcgg gacatcctcc cctctgactg tgcagcctca
 661 gcctccgact ccaacacaga ccatctggat ctgggcatag agttctcagc ctcggcggcg
 721 tcgggggatg agcttgggct ggtggaagag aagccagccc cgtgcccatc cccagaggtg
 781 ctgttaccca ggctgggctg ggatgatgag ctgcagaagc cgggggccca ggtctacatg
 841 cacttcatgc aggagcacac ctgctacgat gccatggcga ccagctccaa actggtcatc
 901 ttcgacacca tgctggaggt gaggccacgc ctcagccccc cccatcctca ccccccccca
 961 ggatgccttg ccagctctgc ccccctccaa gcccccttccc gaactccttc cggcatgaat
1021 ggagaccggg ggagggcttc tgctctctgc acgcacccct taattgtcat cccagctctg
1081 caactcagta tccagagata ggaatgcctg ctttagcctg cgaatttcag aggattcctg
1141 ggacaagcca ggcaatatat gaaagtcttt gcagggtggc ttaggacaaa gagcaaggga
1201 ctcttggtaa gagaaaaata ggatgagctc tgctccccac tcttccctta ggttaaacta
1261 tgaaacattt ggttccgtgc ttctcgctgt gtgcactatt tgattctagt ggaatatgaa
1321 caaatacatt tcatgtagta gctttgtatg ttataatatt agatatttta caatattaga
1381 aaattacagt cagcaggtgt agatagtctt gtttagggtg aggcccaaat aagtcaatgt
1441 aaaatttatt tagggaaaaa tattttgtaa atattataca cataatttca cctctagcac
1501 ttaacaaaat cgatactatg tgtgtctgta cacttatgac tttggagtag aaacactggg
1561 ttggtttccc acaccttgga gtgcttgggg aggggtcacc tcagtacctc tggccaccag
1621 cagccttaga tctggaacaa atgtgcagac aaggatctcg tggagggcat gccaggacgt
1681 gggagaggca gacagcaggc tcatgtagag gcaggcccgg gaggcgcccg gtggaagaac
1741 cctggctggc aggggacctc tgaggcgcag ggaacgattc accctcaact gttctctccg
1801 gcgctcagat caagaaggcc ttctttgccc tggtggccaa cggcgtccga gcggcacctt
1861 tgtgggacag caagaagcag agcttcgtgg gtgaggaggg gctggggagg cagaggtggt
1921 ggggaaggga atagggggac cttgtggggt gattctaggg ccgagctctg acacaccaca
1981 ggcttcaacc aagcaggggc ctggcctgga gaggggggga gcatttgacc ccggtctcct
2041 ggtggccagc tgggagatct caactgtagg agagctgtga ccagctgacc cctccagctc
2101 tactacccca aggtccctgt cgcaggtgct aagtaagaag aggacaggcg gaggaaggaa
2161 gtcagaaaat agaagaagca gggcaggaag gagagaaatg acaggggaag cataagaggg
2221 acaaccccat ttgtcaggca cgggaggggc tgccctcctg tcctcttttg gccaccctca
2281 gtaaaaggat gtgggcaggg tgggggggagg ggcccgggct gacccccatt gctcccctcg
2341 ccccacaggg atgctgacca tcacagactt catcttggtg ctgcaccgct attacaggtc
2401 ccccctggtg aggagtggtc tgggggtcct ggaacaccca tctgggctgg ggtggaagga
2461 gttcagggga ccctcgcctg actttgggag ttccgttgct gtctttaggt ccagatctac
2521 gagattgaag aacataagat tgagacctgg aggggtgagc aggcgagggg acgggcgaag
2581 gggctgaggg tgtgtgggtg aggatggggc caaggacctc agggagagca tgcgcagtgg
2641 aggtttcctg gaggaagcgg gaggagggtg atcgggagcc caggggatct aagggaggga
2701 gacagtctgg gggtggccac gtgaggcggg gtggtcggcc cctttgtgct gattctggct
2761 tttcctgcag agatctacct tcaaggctgc ttcaagcctc tggtctccat ctctcccaat
2821 gacaggtgag cttccccagc cgcccactcg agcctccttg ccccgcacag acccccttctc
2881 cagctcatcg gttctaagct catggactca tcgtccgtgg actgcagatg cggcagcttt
2941 gacaccctgt cctcctctcc agggggggctg ggatgaaggg gctctctttc cagactgccc
3001 caggctcact gctcccacct ccacagcctg ttcgaagctg tctacgccct catcaagaac
3061 cggatccacc gcctgccggt cctggaccct gtctccgggg ctgtgctcca catcctcaca
```

3121 cataagcggc ttctcaagtt cctgcacatc tttgtgagcc tgggcacagc ctcagggaca
3181 acctgagtgg ctgagaagtc ttcagcccta gggatggggg agggagtagc tgggagcccc

FIGURE 4 (continued)

```
3241 ctgagggcta ctccctcctg gcctcacctg tcccaaccca accagggcac cctgctgccc
3301 cggccctcct tcctctaccg caccatccaa gatttgggca tcggcacatt ccgagacttg
3361 gccgtggtgc tggaaacggc gcccatcctg accgcactgg acatcttcgt ggaccggcgt
3421 gtgtctgcgc tgcctgtggt caacgaaact ggtacctatg cccaggatgg gggctctggc
3481 tgtgatggga ctgcgggggg gcaggggtct aggtggcatc aacttggggt ccagcatgga
3541 gtcagggcta gcagtctctg ccttctttga gctttggacc agttgcttag cctctctgag
3601 ccagacctca agttcttcct ctgaaaaaga cttaaaggaa ccatggctgc acactgtttc
3661 aaggttaaat tcaccataaa gaagccagat atcgagaagt attttaattt atgtttgatt
3721 atgaaacatt tccaatgtct gaacatggca gaaaaaacta taatgaaccc cacgtatcca
3781 cctggattaa ccactgttaa catgatgccg tgaccagttc ttttttttt ttcgtggcca
3841 aagtaattta aaggaaatta tattatagaa ttatgtcatt tcaccccggg acacttcatc
3901 tgcctctctt aaaataaggg tacttcctat atcaccttac aattatgaat aatttattaa
3961 tgctatctaa tatccaatcc taattctcat ttctccattt tccccaagaa tatctttttt
4021 ttttttaaca gttgatttgt tgagaccaag atccaatcaa ggtccatgtt tcgcatttgc
4081 ttctttttc ccttaagcct cttttaatct agaacagttc cctccttgct ttattttcgt
4141 gacaccggtg atgagaagct gggtcagttg tcctgtagaa tgtcacactt tgagagattt
4201 gcctgttagc tttccacagg tagcccttat ttttttctc tattcctgcg tttcctgtga
4261 ccgggaaatt agctctaaag gctggatcag attcaggcta gacatttgaa cctagaatat
4321 ttcagaggtg atgccatgta ctcctgtctc atcatattag gaggcatgac ggcaggtgtg
4381 tctctctgtg tgatgctatt tgatctgtgg gctcaggtgc tggccgtctg atgcctcact
4441 ataaagccgg tagcgtgagg ggtggggagt tcattcccaa accccacccc aggccctcgc
4501 tcannatcct ggntctgacc caaacctctc ccctgtcttt ctcacacctt cctccctgcc
4561 cctcccatcc cccacaggac aggtagtggg cctctactct cgctttgatg tgatcgtaag
4621 tatctatggg gaacggaggg gacctggggg accacaggga ggctgtggtg tgaagatgga
4681 tggaggttgg tatctgtgga ccagggaggc ctttacagtg tatatagaga gattatttgt
4741 gggactggag cctggccgag ggctaagaat ggtccccct ccctgcccag cacctggctg
4801 cccaacaaac atacaaccac ctggacatga atgtgggaga agccctgagg cagcggacac
4861 tgtgtctgga aggcgtcctt tcctgccagc cccacgagac cttgggggaa gtcattgacc
4921 ggattgtccg ggaacaggta ccccagcccc ttcatgcctg ctcccaacat gtagggcccc
4981 gtcctcctcg tgagcagctc cagctagccc atccaccggg cacctgtccg gccccccat
5041 cccccattct catggccaag ctcatggtgt ccatattggc cagtgactgg tcctattatc
5101 ggggccctca gggcaagggc cacagccagc tgatcaccca gggtggtcac agccacccgt
5161 aagcagtttc taggagaccc tctgaggcac ccccagttag gttaagttgt tgcccctgat
5221 tctcagtgcc aacctcattg gccgccatag ccgcatggca ctgccccctc actgagcctc
5281 tgtgggccca caggtgcacc gcctggtgct cgtggatgag acccagcacc ttctgggcgt
5341 ggtgtccctc tctgacatcc ttcaggctct ggtgctcagc cctgctggaa ttgatgccct
5401 cggggcctga gaaccttgga acctttgctc tcaggccacc tggcacacct ggaagccagt
5461 gaagggagcc gtggactcag ctctcacttc ccctcagccc cacttgctgg tctggctctt
5521 gttcaggtag gctccgcccg gggcccctgg cctcagcatc agcccctcag tctccctggg
5581 cacccagatc tcagactggg gcaccctgaa gatgggagtg gcccagctta tagctgagca
5641 gccttgtgaa atctaccagc atcaagactc actgtgggac cactgctttg tcccattctc
5701 agctgaaatg atggagggcc tcataagagg ggtggacagg gcctggagta gaggccagat
5761 cagtgacgtg ccttcaggac ctccggggag ttagagctgc cctctctcag ttcagttccc
5821 ccctgctgag aatgtccctg gaaggaagcc agttaataaa ccttggttgg atggaatttc
5881 cacactcg
```

Figure 5

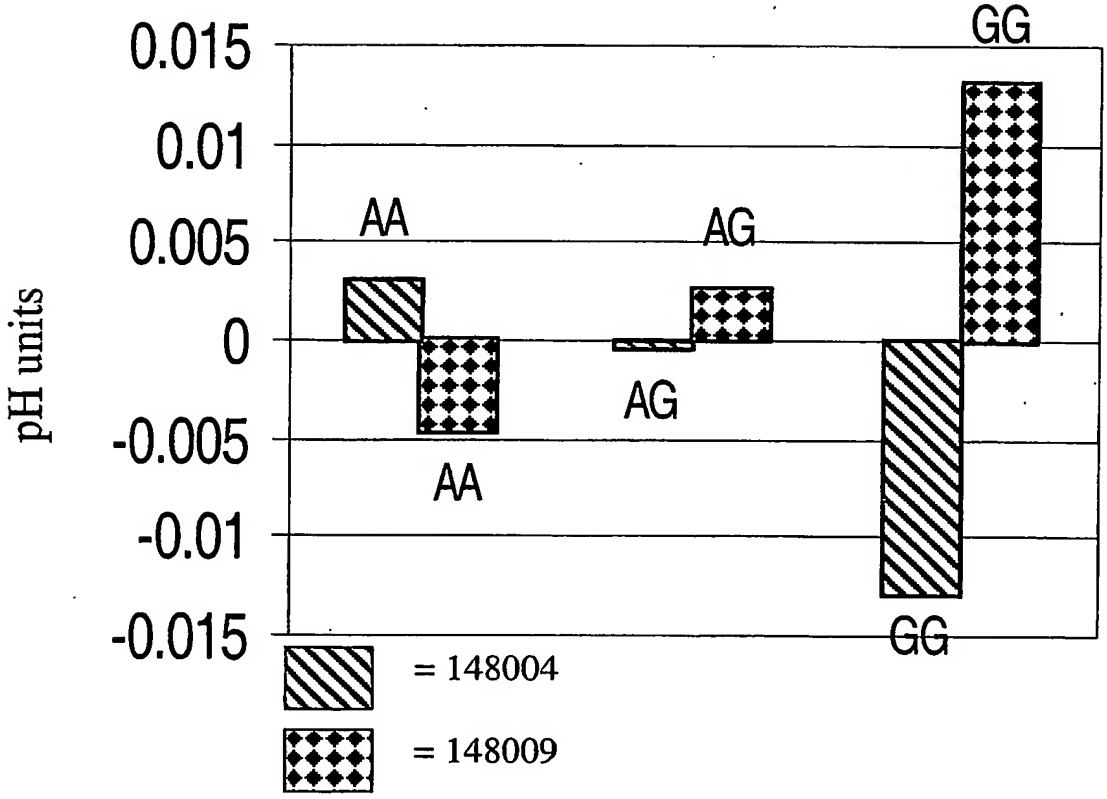
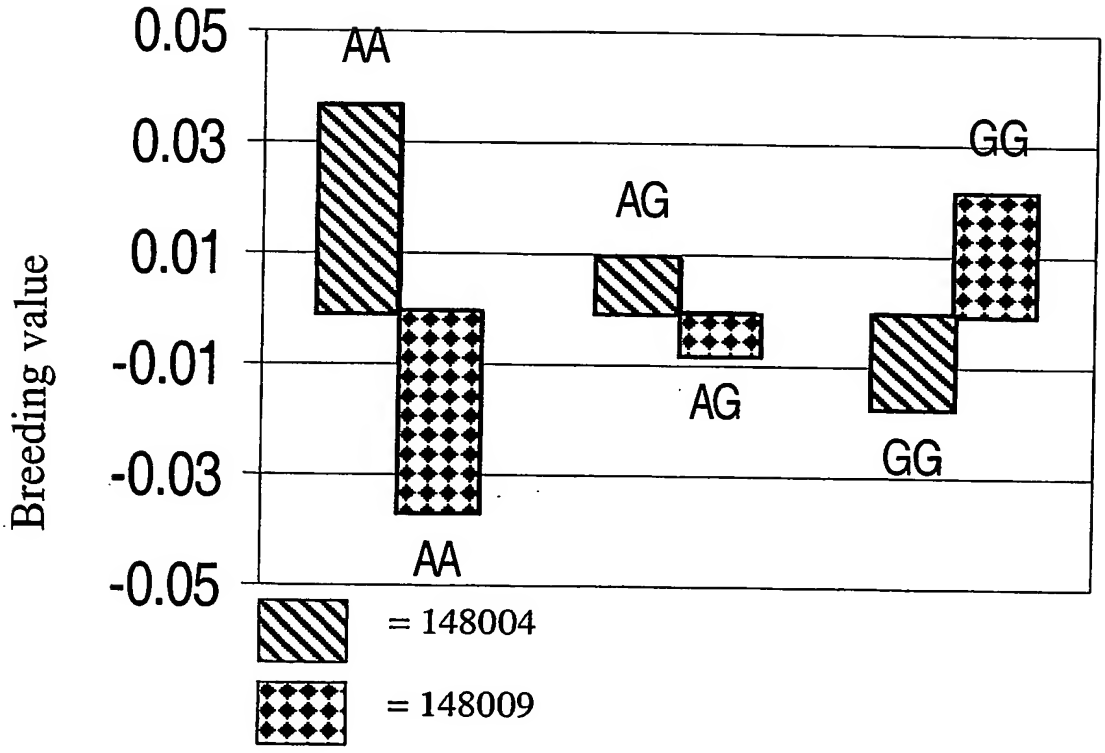

0.015
0.01
0.005
0
-0.005
-0.01
-0.015
pH units
AA
AA
AG
AG
GG
GG
= 148004
= 148009

Figure 6


0.05
0.03
0.01
-0.01
-0.03
-0.05
Breeding value
AA
AA
AG
AG
GG
GG
= 148004
= 148009

GCACTGTTTGAGCACTTGGAAAGTTAAATAATTATTGTTGGAGACTGCATGTTTTAATCTTAGA
TACTTCCTATTTATGTCTTAGTCAAAATGATTAATTGCTTTTCTATGTGTCTTTTAAATGTCCT
AACA GAA TTT ATT TAT GTG ATA ACT GCA TTT GAC TTG
E F I Y V I T A F D L

GCA TAT CCA ATT ACT CCT TGG AAA TTT AAG TTG TCT TGC ATG CCA
A Y P I T P W K F K L S C M P

CCA AAT ACA ACA TAT GAC TTC CTC TTG CCT GCT GGA ATC TCA AAG
P N T T Y D F L L P A G I S K

AAC ACT TCA ACT TTG AAT GGA CAT GAT GAG GCA GTT GTT GAA
N T S T L N G H D E A V V E

A**[T/C]**G GAA CTT AAT **[T/A]** **[C/T]**A AGT GGT ACC TAC TTA TCA AAC
M/T E L N **S/I** S G T Y L S N

TTA TCT TCT AAA ACA ACT TTC CAC TGT TGC TTT TGG AGT GAG GAA
L S S K T T F H C C F W S E E

GAT AAA AAC TGC TCT GTA CAT GCA GAC AAC ATT GCA GGG AAG G
D K N C S V H A D N I A G K

Figure 7